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WADC TECHNICAL REPORT 52-286

A PLASTIC DRESSING (AEROPLAST) FOR BURNS AND SURGICAL WOUNDS

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DECEMBER 1952

WRIGHT AIR DEVELOPMENT CENTER

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Daniel S. J. Choy, Capt, USAF, MC
Aero Medical Laboratory

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FOREWORD

This Report by Captain Daniel S. J. Choy, USAF, MC, the project engineer, was prepared under Research and Development Order No. 696-69, "Human Thermal Tolerance." The work was performed under the auspices of the Aero Medical Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. The experimental work described in Section I was performed in collaboration with Captain Wallace E. Wendt, USAF, VC, at the Aero Medical Laboratory and Sampson Air Force Base. The clinical investigations described in Section III were conducted on the III Surgical Division, Bellevue Hospital, New York City, New York. The author is indebted for the invaluable assistance of Technical Sergeant James Edwards.

ABSTRACT

In August 1951, the author initiated a project to develop a rapidly applied, sprayable, film-forming plastic to be dispensed from aerosol bombs or other spraying equipment, for the mass local therapy of burns.

This report of the achievements of this project is divided into three Sections:

Section I is concerned with the treatment of experimental burns on hogs with the plastic dressing and the evaluation of the plastic for possible local and systemic toxicity.

Section II deals with studies on comparative wound healing rates in rats, using the plastic dressing and a control dressing of vaseline gauze.

Section III describes the clinical trials of the aeroplast dressing on burns and a wide variety of surgical wounds in humans.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:

Robert H. Blount

ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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SECTION I

A LOCAL TREATMENT OF BURNS AND SURGICAL WOUNDS

Present-day warfare, especially bombardment with nuclear reactors, brings with it the threat of hundreds of thousands of burn casualties produced within a moment. Pearse and Payne[1] estimate that from 65 to 85% of all casualties resulting from an atomic explosion will have thermal injuries. The need for revision of traditional methods of burn therapy is evident. Research into this problem has been directed toward the development of plasma expanders and the development of new technics of local therapy.

Nearly all of the technics of local burn therapy today are variations of the classical ointment-gauze pressure dressing. The disadvantages of this method and its modifications are: (1) the dressings are bulky and require much storage space; (2) they require periodic re-sterilization; (3) their application requires a fairly high level of training, and is time-consuming; (4) the dressings are poorly adapted to some parts of the body; (5) around limbs they may produce a tourniquet effect, leading to stasis, phlebothrombosis, and tissue anoxia; (6) around the thorax or abdomen they restrict respiration; (7) massive pressure dressings in hot weather have been observed to result in elevation of body temperature and discomfort; and (8) inspection of the lesion is not possible without removal of the dressing. It is only fair to state that the hydrolyzed casein gel dressing of Curtis et al.[2] has been used with success on 22 patients by Spangler[3].

The open-air method dispenses with the logistical problems posed by the pressure-bandage technic, but its inherent limitations are (1) its inapplicability to circumferential burns; (2) the unrestricted local loss of tissue fluids; (3) swelling; (4) the great nursing load during the drying-out period; and (5) the difficulties of transporting the patient.

Against this background, we envisaged an occlusive type of dressing which could be sprayed on over a burn by relatively untrained personnel in minimal time. The dressing would seal contaminants out and vital fluids and electrolytes in. We thought that a nontoxic, biologically and chemically inert, adhesive, elastic, transparent, rapidly drying, film-forming, and peelable plastic, dispensed from an aerosol bomb or spray gun, would best meet this requirement and overcome most of the difficulties enumerated for standard burn dressings. Of a number of plastics tested in the laboratory,

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1/ Pearse, H. E., and Payne, J. T.: Medical Progress; Mechanical and Thermal Injury from Atomic Bomb. New England J. Med. 241: 647-653, 27 October 1949

2/ Curtis, R. M.; Brewer, J. H.; and Rose, Il W., Jr.: New Technique for Local Treatment of Burns. J. A. M. A. 147: 741-743, 20 October 1951

3/ Spangler, P. E.: New Local Treatment for Burns. U. S. Armed Forces M. J. 3: 105-114, January 1952

a modified polyvinyl chloride acetate copolymer in ethyl acetate solvent (XC7-9C) was selected for evaluation as a plastic dressing (aeroplast) to be sprayed on experimental animals.

Methods:

Preliminary studies included tests for permeability to bacteria and bacteriostatic properties and gross qualitative tests for adhesiveness to skin, elasticity, water resistance, flexibility, and permeability to water vapor.

"Gloves" of aeroplast averaging from 2 to 3 mils in thickness were applied to the (unburned) digits and hands of several subjects by immersion or spraying. The subjects were then instructed to go about their daily affairs without favoring the gloved digit or hand. Inspection of the glove was made 24 hours later. In all cases, the gloves were found to be adherent, except at the edges; sufficiently elastic and flexible after 24 hours to permit maximum flexion and extension of a digit without cracking; waterproof; and sufficiently permeable to the diffusion of water vapor so that no "water blisters" formed from trapped perspiration. The plastic peeled off easily, exposing skin that was not puckered or wrinkled. There were no complaints of subjective discomfort.

Bacteriologic studies indicated that films from 2 to 3 mils thick were impermeable to motile coliform group organisms, and when sprayed on to seeded agar plates, possessed a moderate bacteriostatic effect (Fig. 1).

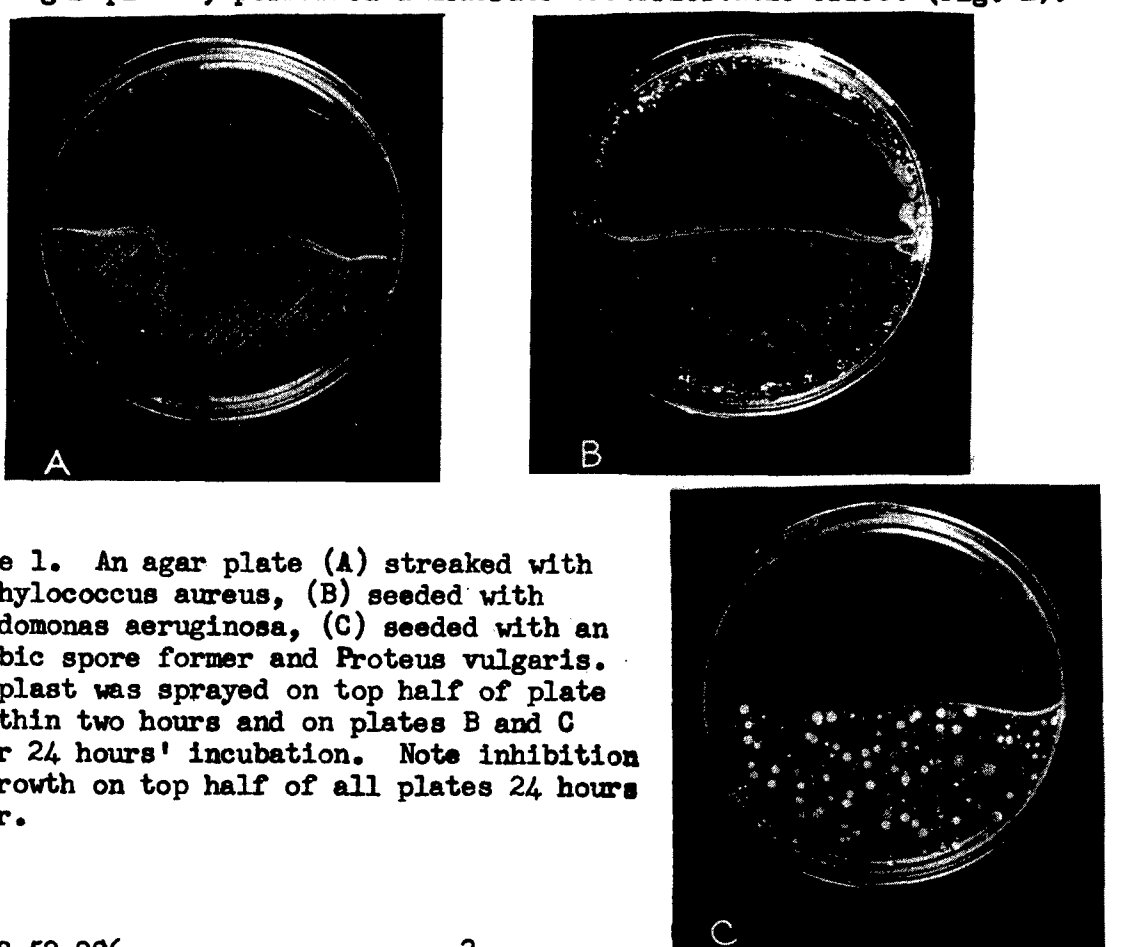


Figure 1. An agar plate (A) streaked with Staphylococcus aureus, (B) seeded with Pseudomonas aeruginosa, (C) seeded with an aerobic spore former and Proteus vulgaris. Aeroplast was sprayed on top half of plate A within two hours and on plates B and C after 24 hours' incubation. Note inhibition of growth on top half of all plates 24 hours later.

Clinical. Chester-White, weaned, healthy male and female hogs, from six to eight weeks old, weighing from 15 to 20 kg were used because of the histologic similarity between hog and human skin[4]. Barbiturate anesthesia was given through an ear vein. Complete blood counts were made before burning and repeated at intervals of from two to seven days. Color photographs were taken immediately before and after burning, after aeroplast was applied, and repeated serially every five to seven days. A standard burn pattern was made by cutting arbitrarily shaped windows in a one-fourth inch thick sheet of asbestos. With this shield in place, a third-degree burn, involving about 20 percent of the body surface, was applied with a blow torch to the clipped dorsal surface of the animal (Fig. 2). Joints and orifices were avoided. A biopsy specimen of burned skin was then taken.

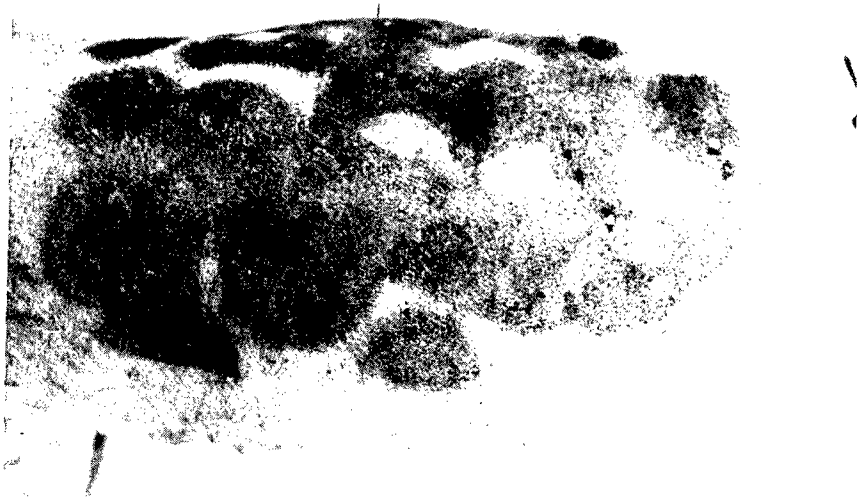


Figure 2. Pattern of burn on dorsal surface of hog

The degree of burn was judged (1) clinically, to be third-degree when the skin turned from a normal pink to a charred yellow and formed a rigid, depressed eschar which eventually sloughed off as re-epithelization occurred, and (2) histologically, to be third degree when there was full-thickness destruction of the epidermis and coagulation necrosis of more than the upper fourth of dermis[5].

4/ Moritz, A. R., and Henriques, F. C., Jr.: Studies on Thermal Injury; Relative Importance of Time and Surface Temperature in Causation of Cutaneous Burns. Am. J. Path. 23: 695-720, September 1947.

5/ Christopher, F.: Textbook of Surgery. 3d edition. W. B. Saunders Co., Philadelphia, Pa., 1942. p. 60

Aeroplast was sprayed on the burned area with an ordinary paint sprayer within 10 minutes of the burning. The ethyl acetate solvent evaporated within from 15 to 20 seconds, leaving a tough, elastic, and transparent plastic film 2 or 3 mils thick (The tensile strength of a 6 mil thick film at 70°F is 1332 psi.) adhering to the burned areas and the surrounding, healthy skin. From 150 to 300 cc of isotonic saline solution was administered intraperitoneally to each animal.

The open-air method of therapy was employed in the control animals because it was found technically not feasible to apply and maintain the integrity of conventional pressure bandages in the ambulatory hog.

On recovery from anesthesia, the animals were allowed protein-supplement hog feed and fluids ad lib. All animals were ambulatory from recovery of consciousness to autopsy. When complete healing had occurred, the animals were sacrificed by exsanguination. Sections were taken of skin, heart, lungs, kidneys, liver, adrenals, and spleen for histologic study.

Results:

Aeroplast was exposed to traumatic conditions which would not obtain in the case of a human being. Because of cramped quarters, the dressing was repeatedly chewed on by the hogs and abraded against the wire fence. Despite these conditions, the dressings remained intact for an average of three days. After seven days, an average of 35% of the burned area was exposed. Healing of the burns occurred with eschar formation, sloughing, and re-epithelization with moderate cicatrix formation (Fig. 3). There was a relative absence of local infection.

Third-degree burns involving 20% of the body surface was administered to 18 hogs, four of which were controls. This report includes only 11 hogs on which complete data are available. Of the 11 being reported, three were controls (Table 1).

Of the control group, one exhibited about 68% skin regeneration at death from bronchopneumonia 28 days after the burn. One died eight days after burn, and had sloughing of the burn and no healing. Death was due to so-called "burn toxemia" characterized by cloudy swelling of the kidneys, and diffuse punctate hemorrhages in the adrenal cortex, pulmonary parenchyma, epicardium, and gastrointestinal tract (Fig. 4). One exhibited complete regeneration of the skin after 43 days, and at autopsy no pathologic changes were noted.

Of the treated group, one exhibited 85% skin regeneration at death from pneumonitis, bacteremia, and metastatic abscesses in liver and gastrointestinal tract (Fig. 5) 28 days after the burn. One died after eight days and had sloughing on the burn and no healing. Death was due to acute lobar pneumonia and focal necrosis of the liver (Fig. 6).

The remaining six exhibited complete regeneration of the skin with moderate cicatrix formation (Fig. 7), from 24 to 37 days after the burn. Of these, one exhibited cloudy swelling of the liver; one, focal hydropic

TABLE 1. *Summary of findings following burns*

Hog number	Number of days required for healing*	Days after burn when autopsy was done	Diagnosis at autopsy	Skin	Liver	Kidneys	Adrenal cortex	Lung
Controls								
5	65-70 % in 28	28	Broncho-pneumonia	Ulceration, focal epi-dermization	NPC	Slight chronic pyelone-phritis	NPC	Broncho-pneumonia
6	-	8	"Burn toxemia"	Eschar formation	NPC	Cloudy swelling	Hem. zona fascic.	Hemorrhage
12	43	43	**	CR	NPC	NPC	NPC	NPC
Treated								
1	24	35	**	CR	NPC	NPC	NPC	NPC
3	28	28	**	CR	Cloudy swelling	NPC	NPC	Recent focal hemorrhage
4	37	71	**	CR	NPC	NPC	NPC	Partial atelec-tasis and ascariasis
7	85% in 28	29	Pneumonitis, bacteremia, and meta-static ab-scess	85% regen-eration	Hyperemia and small focal ab-scesses	Slight cloudy swelling	NPC	Acute inter-stitial pneu-monitis

TABLE 1. *Summary of findings following burns*—Continued

Hog number	Number of days required for healing*	Days after burn when autopsy was done	Diagnosis at autopsy	Skin	Liver	Kidneys	Adrenal cortex	Lung
Treated—Con.								
8	33	33	**	CR	NPC	Focal hydropic degeneration of the tubular epithelium	NPC	NPC
9	35	45	**	CR	NPC	NPC	NPC	NPC
10	27	31	**	CR	NPC	NPC	NPC	Partial atelectasis and ascariasis
11	-	10	Lobar pneumonia	Eschar formation	Hyperemia and focal necrosis	NPC	NPC	Acute lobar pneumonia

*Healing was complete (100%) unless lower percent is indicated.
**Animal sacrificed by exsanguination.
NPC = No pathologic change.
CR = Complete regeneration.

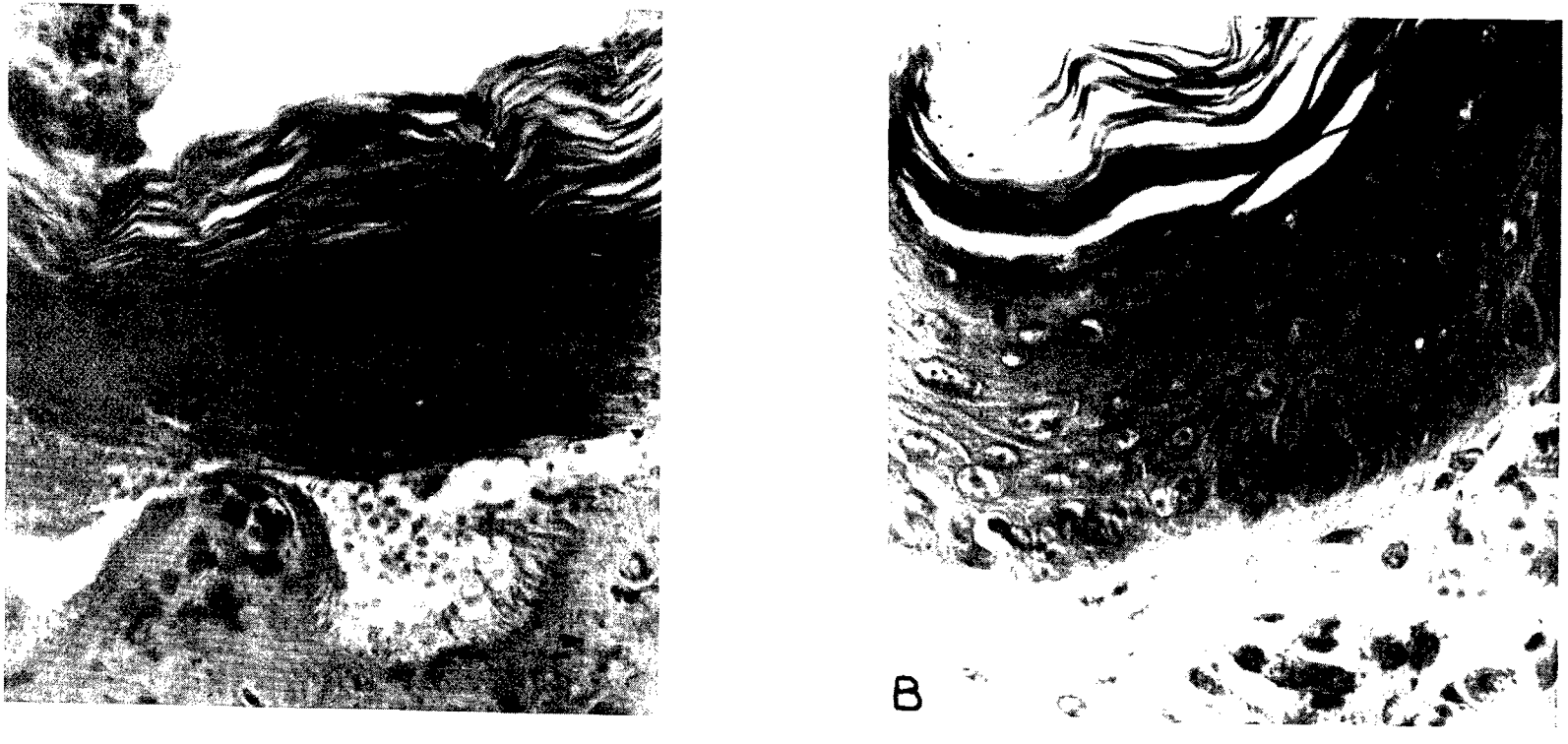


Figure 3. (A) Third-degree burn of skin. Note loss of cellular architecture of epidermal epithelium, subepidermal hemorrhage, and coagulation necrosis of dermal elements. (B) 45 days after burn. Note essentially normal epidermal epithelium.

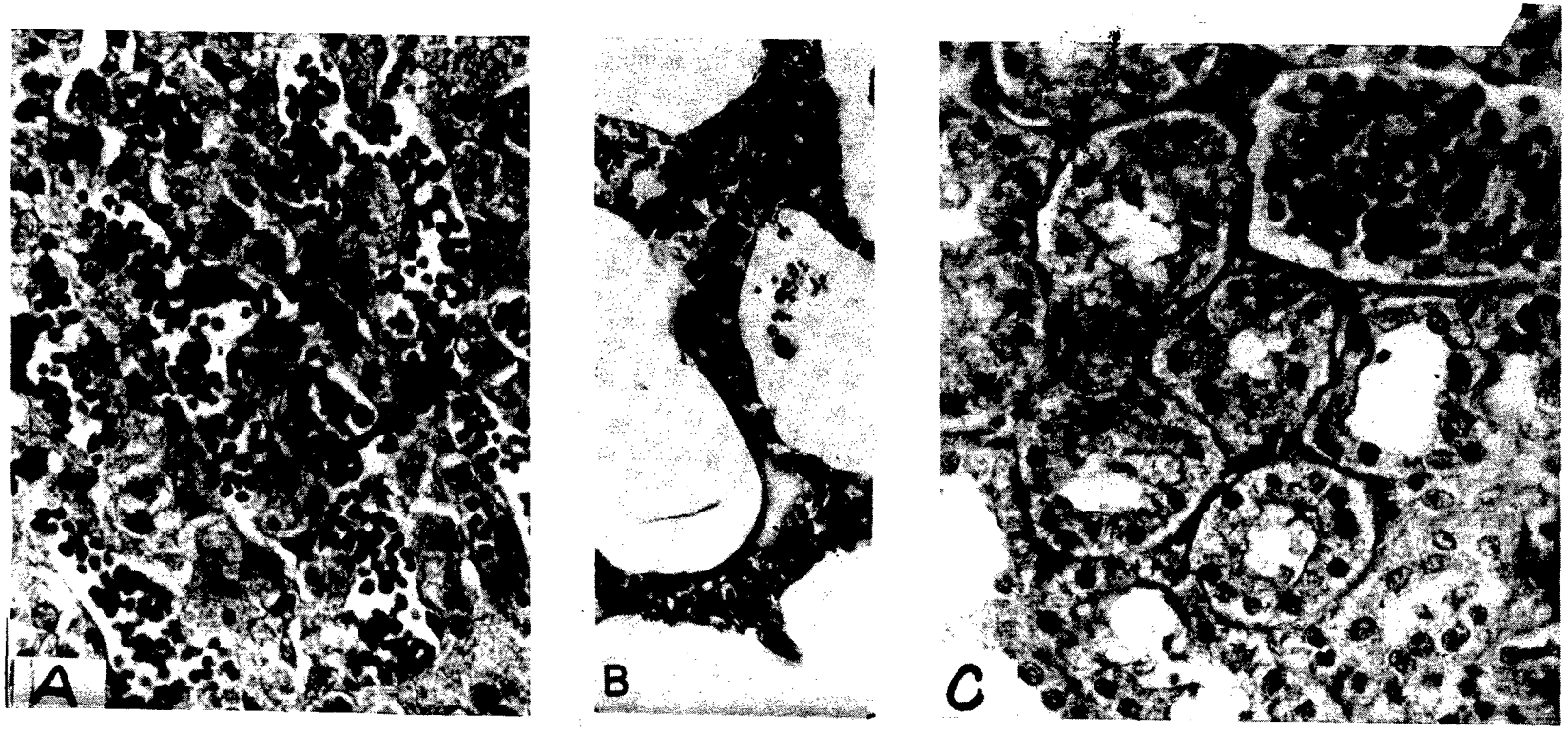


Figure 4. (A) Section of adrenal cortex showing hemorrhages in zona fasciculata. (B) Section of lung showing intra-alveolar hemorrhages. (C) Section of kidney showing cloudy swelling.

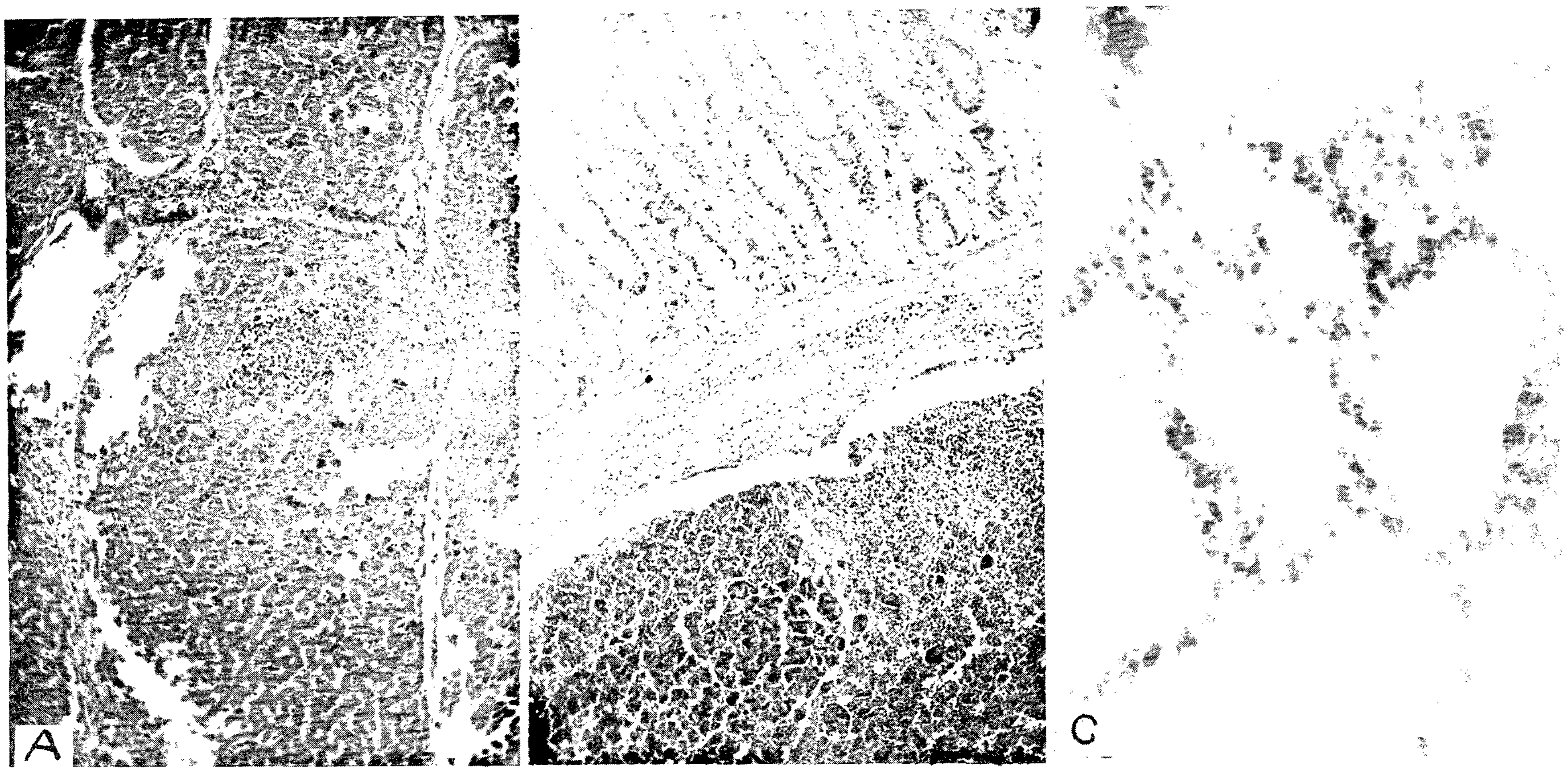


Figure 5. (A) Section of liver showing small focal abscess. (B) Section of intestine showing submucous abscess. (C) Section of lung showing acute interstitial pneumonitis.

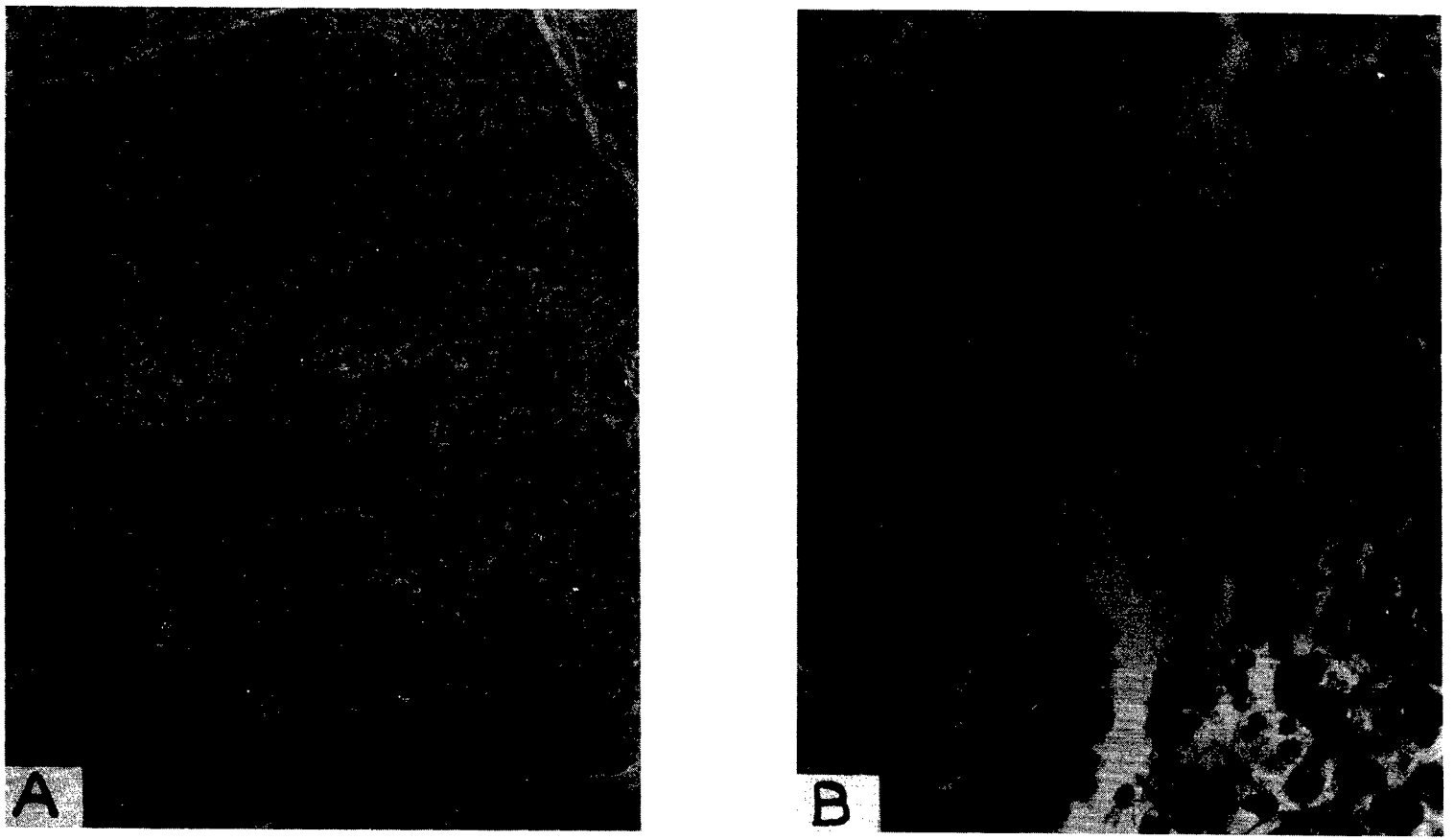
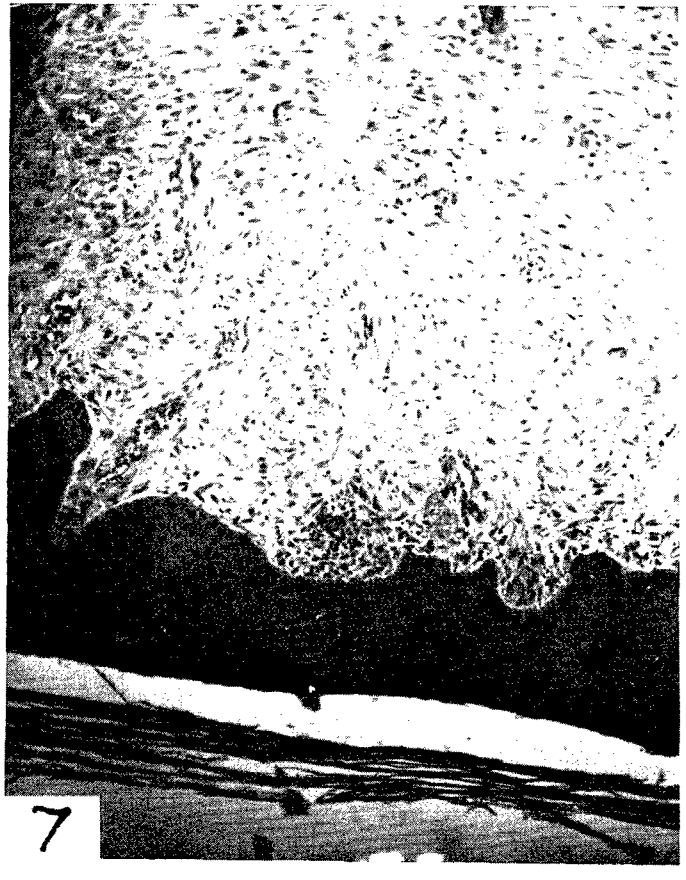


Figure 6. (A) Section of liver showing focal necrosis. (B) Section of lung showing acute lobar pneumonia.



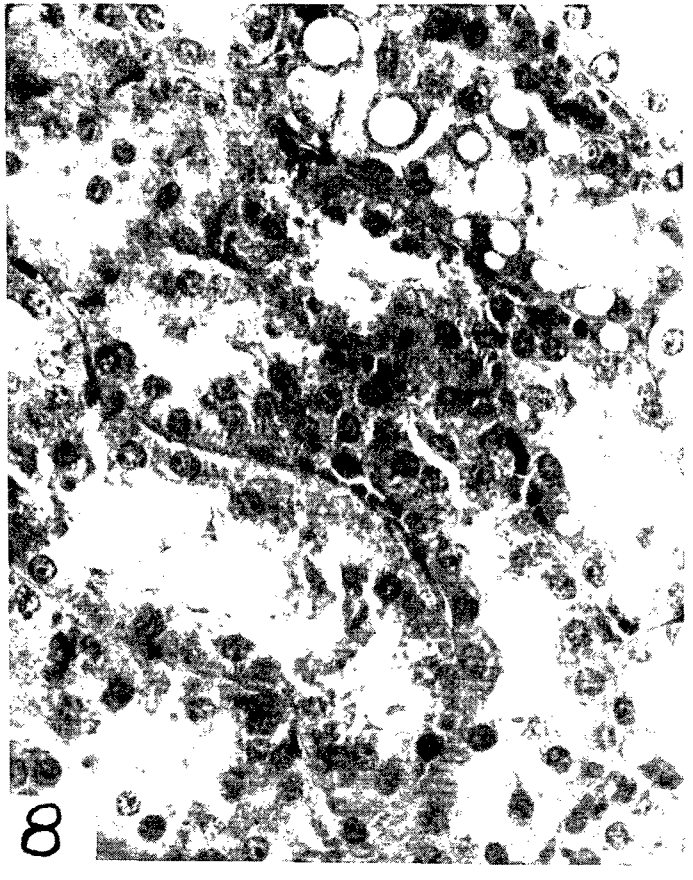


Figure 7. Section of skin, 33 days after burn, showing complete epidermal regeneration with moderate dermal cicatrix formation.

Figure 8. Section of kidney showing focal hydropic degeneration of tubular epithelium.

degeneration of the renal tubular epithelium (Fig. 8); and two, nematode infestation of the lungs with partial atelectasis. No other pathologic findings were noted.

Toxicity:

Little or no toxicity was expected from the use of aeroplast because its base is a chemically inert vinyl resin. The properties of its solvent, ethyl acetate, are well known. In air concentrations lower than 400 p.p.m., it is nontoxic; above this level, it can produce headache and mild narcosis if inhaled, and irritation to conjunctiva, gums, and respiratory passages by contact. Chronic poisoning leads to secondary anemia, leukocytosis, and cloudy swelling and degeneration of viscera[6/]. Because of its rapid evaporative loss, its contact time with the burn lesion is negligible; with initial dry spraying (spraying with the spray nozzle at some distance from the skin so that the initial layer is dry vinyl plastic, which forms an insulation barrier) it is possible to reduce the contact time to zero. Because it is not envisaged to apply aeroplast more than once to each patient, the problem of chronic poisoning does not arise. Aeroplast is, however, inflammable, and suitable precautions should accompany its use.

Patch tests were performed to determine possible local irritant or toxic effects. The aeroplast was applied with an applicator to a 1 sq cm area on the volar surface of the shaved forearm and was covered with a band-aid. The area was inspected at 24 and 48 hours for signs of irritation. Of 1052 subjects tested, five showed a ± to + reaction (doubtful to slight erythema in 24 hours, and three showed a ± to + reaction in 48 hours (Table 2). Those who exhibited positive reactions in 24 hours were negative in 48 hours and those who exhibited positive reactions in 48 hours had been negative at 24 hours. The total number of subjects reacting to aeroplast was eight or 0.76%. By contrast, it was noted with interest that about 20% of the group exhibited mild to severe reactions to the band-aid.

Reactions after	24 hours	48 hours
0	1047	1049
±	4	2
+	1	1
Percent of positive reactions*	0.48	0.29

*Including ±

Table 2. Results of patch-testing with aeroplast on 1052 subjects

6/ Sax, N. I.: Handbook of Dangerous Materials. Reinhold Publishing Corp., New York, N. Y., 1951. p. 58

Inasmuch as vinyl polymer is insoluble in tissue fluids, the question of systemic toxicity from absorption (as in the case of tannic acid[7]) was considered to be more hypothetical than real. Observations were, however, made of the hematologic, renal, and hepatic systems. Serial blood counts revealed no evidence of myeloid depression and no morphologic changes of the erythrocytes such as those commonly associated with various system poisons.

Of the treated group of eight animals, one had small focal abscesses, one had focal necrosis, and another (hog 3) had cloudy swelling of the liver (Table 1). The first, however, was associated with pneumonitis and bacteremia with diffuse metastatic abscesses and the second with acute lobar pneumonia, both bearing possible etiologic relationship to the hepatic changes. The third, sacrificed by exsanguination, had no other pathologic finding.

Focal hydropic degeneration of the tubular epithelium was observed in one of the treated hogs. The significance of this and the cloudy swelling of liver in hog 3 is difficult to evaluate in the light of well-known hepatorenal changes in "burn toxemia." The evidence suggests an absence of systemic toxic effect from polyvinyl chloride acetate copolymer.

Discussion:

This form of local burn therapy has these advantages: (1) a marked saving of time over conventional pressure dressings in application (Fig. 9); (2) the feasibility of its use by relatively untrained personnel; (3) applicability to parts of the body poorly adapted to pressure dressings; (4) transparency allowing frequent inspection of the burned area without removal of the dressing; (5) flexibility allowing relatively unrestricted early exercise of burned hands and digits without loss of integrity of the dressing; (6) impermeability to bacteria; (7) moderate bacteriostasis; (8) reduction of local loss of electrolytes and fluids and sealing of proteolytic enzymes within the area of the burn, thus enhancing autodebridement and early sloughing of eschar in third-degree burns; (9) elimination of necessity for periodic resterilization; (10) minimal storage problems; (11) the absence of tourniquet effect on limbs and restriction of respiration when applied to the abdomen or thorax; (12) portability and feasibility of use under adverse conditions in the field; and (13) adaptability to the mass therapy of burns.

These considerations are advanced with the inescapable premise in mind that adequate systemic therapy with fluid and electrolyte replacement, antibiotics, analgesics, and tetanus antitoxin, take precedence over any form of local therapy, however effective. No statistically valid conclusions can be derived from such a small series, especially with reference to relative healing times of the control and treated groups. It can only be stated that results so far are encouraging. Further evaluation of aeroplast on animals, with emphasis on possible toxicity, is indicated.

7/ Jackson, A. V.: Liver Necrosis in Burns Treated with Tannic Acid. M. J. Australia 2: 352-354, 30 September 1944

Summary:

Burn therapy technics need revision in view of the demands of atomic warfare. A method of local treatment of burns, using aeroplast has been tried on 11 hogs with excellent results.

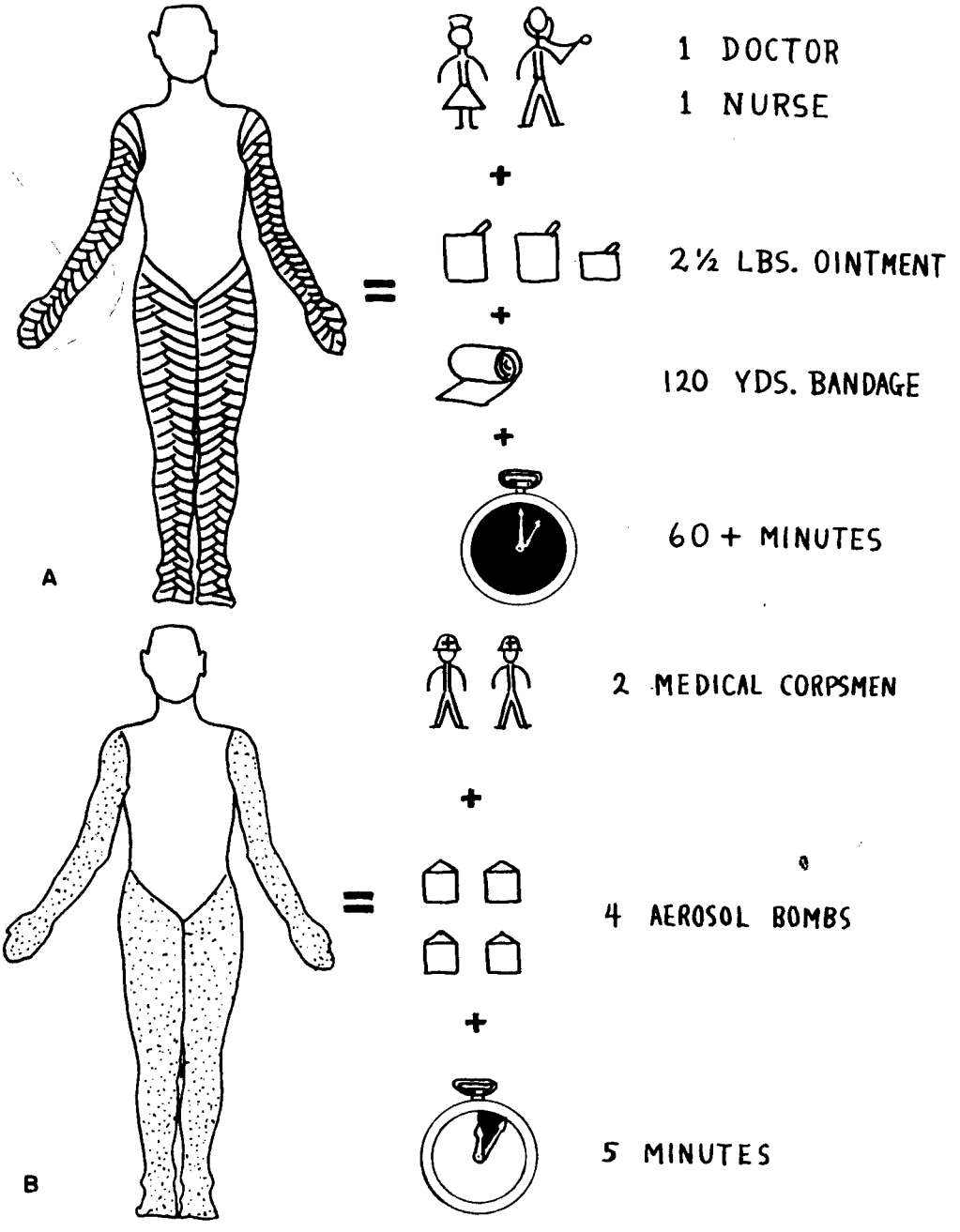


Figure 9. Comparison of treatment of 50% body burn by (A) Standard pressure bandage and (B) Aeroplast dressing

SECTION II

COMPARATIVE WOUND HEALING RATES OF STANDARD BURN DRESSING AND AEROPLAST

Methods:

Fourteen adult male and female albino rats, Sprague-Dawley strain, weighing 250 to 350 grams, were used. Each animal was anesthetized with nembutal intraperitoneally, and shaved on both sides of the abdomen. Both areas were painted with merthiolate. A circle 1.0 cm in diameter was traced on both sides with a template. The areas were then repainted with merthiolate. With surgically clean (but not aseptic) forceps and curved scissors, the 1.0 cm diameter circular areas of skin were excised, exposing subcutaneous fascia. The skin defects were traced on cellophane. Aeroplast was applied with an applicator stick to the right wound, and allowed to dry, leaving a transparent film approximately 2 mils thick. Petrolatum was applied to the left wound. A sterile 2 x 2 gauze was applied over both wounds and kept in place with adhesive tape wound circumferentially.

The wounds were inspected at three to four day intervals under ether anesthesia, and the defects recorded on cellophane by direct tracing (Fig. 10). At this time, the dressings were changed. Only in three or four instances, when the plastic film was inadvertently removed due to adherence to the overlying gauze, was it necessary to re-apply aeroplast. In the remainder, the original application of aeroplast sufficed until complete healing had occurred.

Results:

Healing times ranged from 13 to 14 days after the operation (Table 3). Of the wounds treated with petrolatum gauze, five healed in 13 days, and nine in 14. Of the wounds treated with aeroplast, six healed in 13 days, and eight in 14.

There was thus no significant difference in wound healing rates in this series of 14 comparisons.

Discussion and Summary:

A study by Brush et al.[8/] of a number of substances recommended for the treatment of burns revealed that among those which delayed wound healing were tannic acid in solution and in jellies, proflavine dihydrochloride, hydrosulphosol, Biodyne ointment, and two types of carbowax base. Wounds dressed with petrolatum gauze healed in the same time as control wounds dressed with dry gauze.

8/ Brush, B. E., Lam, C. R., and Ponka, J. L.: Wound Healing Studies on Several Substances Recommended for the Treatment of Burns. Surgery 21: 662-667, 1947.

In the evaluation of aeroplast as a burn dressing, the question necessarily arose as to whether or not it delayed wound healing. The results of this experiment, with 14 sets of comparisons, indicate that wounds dressed with aeroplast and those dressed with petrolatum gauze heal at identical rates.

HEALING TIME: DAYS	NUMBER OF WOUNDS	
	PETROLATUM GAUZE	AEROPLAST
13	5	6
14	9	8
TOTAL	14	14

Table 3. Comparative wound-healing rates of petrolatum gauze and aeroplast

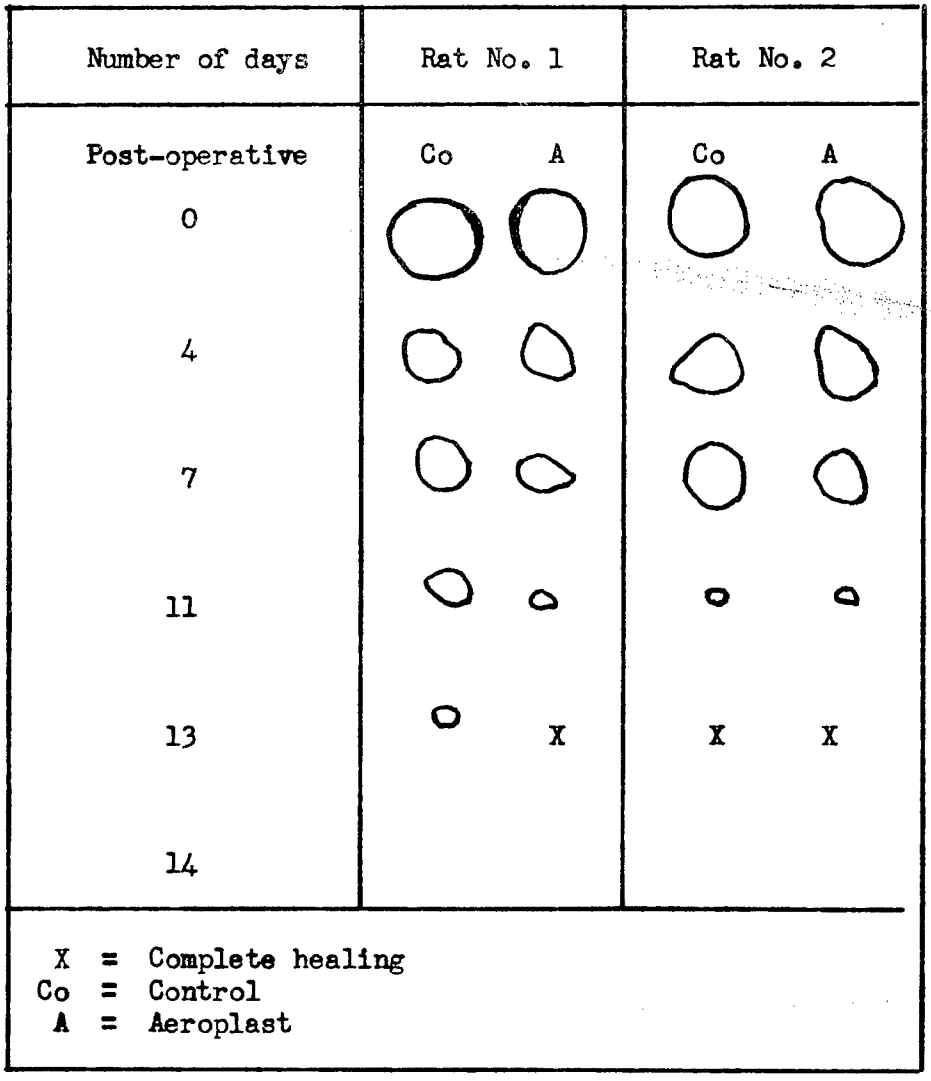


Figure 10. Representative wound-healing rates in two rats using aeroplast and control dressing

SECTION III

CLINICAL TRIALS

Methods:

Clinical trials of the aeroplast were conducted on The Third Surgical Division, Bellevue Hospital, New York City.

All wounds were treated in accordance with usual surgical practice. The aeroplast was then applied either by (1) spraying from an aerosol bomb or a spray gun operated by a portable air compressor, or (2) direct painting onto the lesion with a 2 x 2 on straight forceps or an applicator stick. In all cases, a from 1 to 2 inch margin of normal skin was included in the dressing. Color photographs were taken before and after the dressing and serially during wound healing. Clinical observations were made daily and the aeroplast dressing changed as necessary by simply peeling it off as a sheet and reapplying.

Serial liver profile, renal function, and hematological studies were contemplated to further confirm previous animal experiments demonstrating the nontoxicity of the aeroplast dressing. These, however, were soon abandoned because of the prevalence in our series of cases of acute alcoholism, Laennec's cirrhosis, malnutrition, and pulmonary tuberculosis.

It was decided to include a wide variety of surgical wounds, other than burns, in order to determine the precise areas of efficacy and the limitations of the aeroplast.

Results:

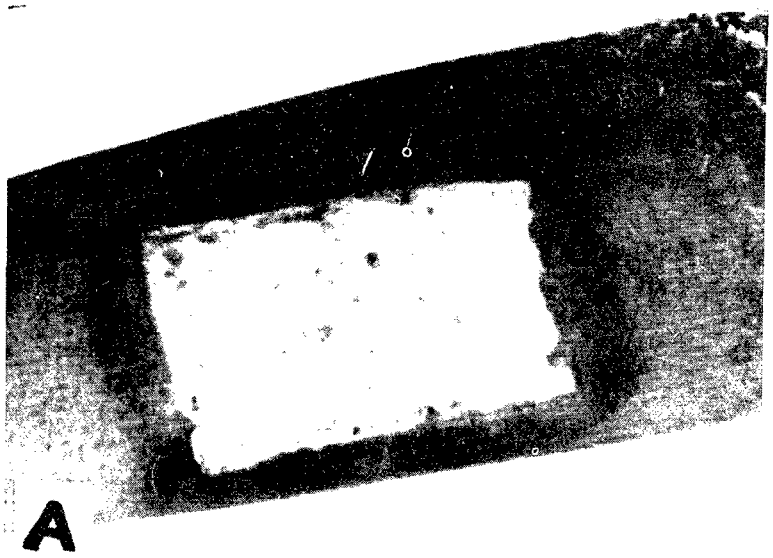
Of a total of 50 cases treated, 11 were burns, from first- to third-degree; 8 were skin-graft donor sites, which were regarded as second-degree burn equivalents; and 31 were other types of surgical lesions, including operative wounds, lacerations of hands, neck, face and scalp, open reductions of fractures, decubiti, granulating wounds and colostomies.

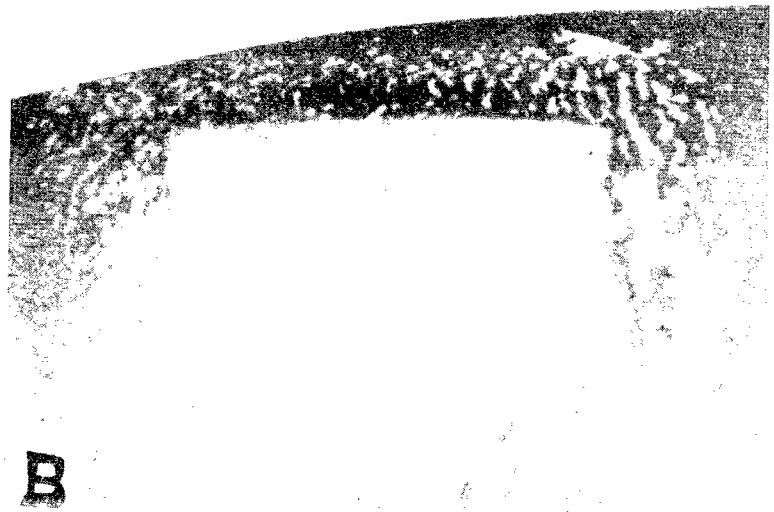
Skin-Graft Donor Sites:

Of the eight skin-graft donor sites treated, all healed without infection in an average of 11 days. (Table 2)

Because of fluid collection underneath the dressing, Case No. 1, E. J. (Fig. 11), required two, and Case No. 2, F. F., and 3, W. H., each required one change of dressing. The remaining five re-epithelialized under the single, original dressing.

Case No. 3 (W. H.), was a chronic alcoholic with active pulmonary tuberculosis and stasis ulcers of the right lower leg. A split-thickness skin graft was taken from the inner aspect of the left thigh. After 76 days,





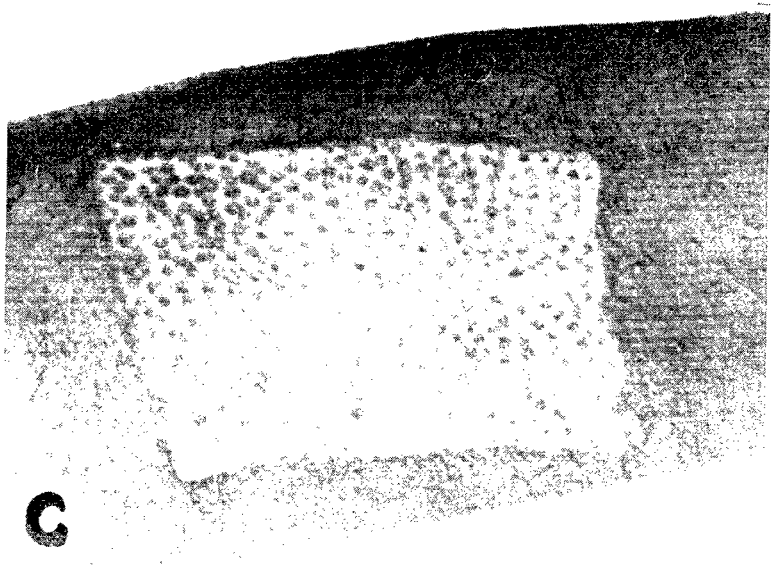


Figure 11. Case 1, E. J. (A) Skin—graft donor site, seven days post operative. (B) Skin-graft donor site with aeroplast dressing, 14 days post operative. Note partial return of pigmentation visible through transparent dressing. (C) Skin-graft donor site, healed, 18 days post operative.

the donor site, treated first with vaseline gauze and subsequently with the open-air exposure method, was approximately 70% non-epithelialized because of repeated infection with B. pyocyaneus and breakdown of the new epithelium. The aeroplast dressing was then tried, successfully, with complete epithelization 10 days later.

Burns:

Of the 11 burns treated, 5 were infected with B. pyocyaneus; of these, 3 were infected prior to, and 2 were infected subsequent to the application of aeroplast. Two were lost to follow-up. The three outstanding observations made were: (1) the aeroplast could be applied very quickly; (2) in first- and second-degree burns there was pronounced subjective relief of pain (after the initial, sharp "stinging" sensation wore off with evaporation of the ethyl acetate solvent; this usually lasted from 30 to 45 seconds) and (3) the transparency of the aeroplast permitted early detection of infection.

Case 1 (E. J.) The patient was a 22-year old, colored male admitted 4 July 1952, for first-, second-, and third-degree burns of the right thigh and leg, sustained when a fire-rocket entered his trouser leg. The first- and second-degree burns healed in from four to seven days with open-air exposure. The third-degree burn measuring 9 x 8 cm was grafted on 30 July 1952. There was an incomplete take (approximately 75%), with a superimposed B. pyocyaneus infection under the pressure dressing. The lesion was exposed for 24 hours before he was first seen by the author. The aeroplast dressing was applied on 7 August 1952 and changed once on 8 August 1952 because of moderate fluid accumulation underneath. The pyocyaneus infection subsided, no other dressings were required and the burn epithelialized completely on 18 August 1952.

Case 2 (C. B.) The patient was a 24-year old, colored male admitted 21 August 1952, for a second-degree friction burn of the entire dorsal surface of the left forearm, sustained in an automobile accident (Fig. 12). He first received surgical attention 12 hours after the injury, at which time the burn was debrided and dressed with vaseline gauze. This was removed on 22 August and aeroplast applied. Between this time and 2 September 1952, the dressing was changed twice because of a low-grade B. pyocyaneus infection. On 2 September, there was no further evidence of infection, and evidence of healing appeared with the return of pigmentation in scattered areas. The burn was completely epithelialized by 8 September 1952.

Case 3 (C. B.) The patient was a 31-year old, white male admitted 23 August 1952, for second-degree circumferential burns of the digits and dorsum of both hands, and second- and third-degree burns of the entire, left, lower leg, except for the plantar surface of the foot, sustained in a gasoline fire. The aeroplast dressing was applied with marked, subjective relief from pain. The patient was encouraged to use his hands, and he did so, so vigorously that the dressing over the finger pads and web spaces had to be "mended" daily by painting over with plastic as breaks developed. On the third hospital day, the blisters over the fingers, hands, left foot and ankle were excised and the aeroplast reapplied. A second change of dressing

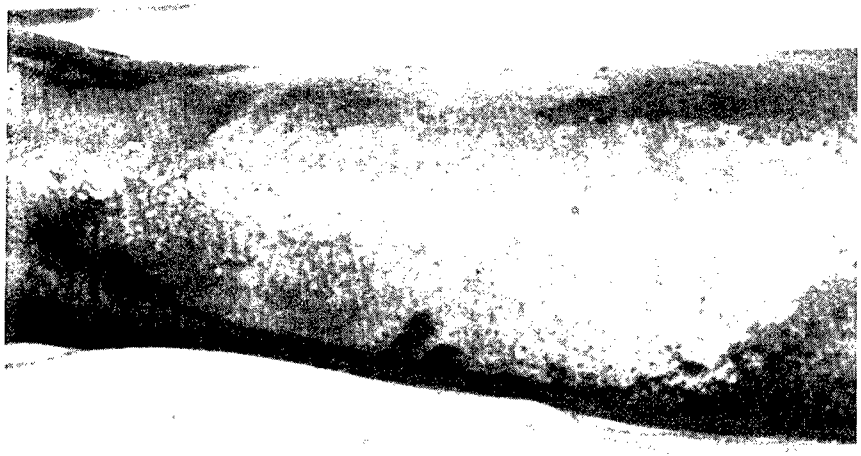


Figure 12. (A) Case 2, C. B. Second-degree burn, dorsum of left forearm.

Figure 12. (B) Case 2, C. B. Second-degree burn with aeroplast dressing.

was done on 29 August. On 2 September 1952, both hands were completely epithelialized with full function. However, the burn on the leg became infected with B. pyocyaneus, the aeroplast was removed, and the burn successively treated with acetic acid soaks, open exposure, antibiotics and physiotherapy. On 29 September 1952, the burn had healed sufficiently to warrant discharge of the patient.

Case 4 (E. W.) The patient was a 54-year old, white male admitted 15 August, with a diagnosis of active pulmonary tuberculosis and a 3 x 4 cm, third-degree burn of the right ankle, sustained on 1 August 1952. On furacin and saline dressings, the burn became grossly infected with B. pyocyaneus. Aeroplast dressings were started on 25 August. Until 4 September, the aeroplast was changed every two-three days with soap, peroxide and saline preparation. The pyocyaneus infection remained stationary; new epithelium from 0.5 to 1.0 cm wide grew in from the margins, and there were healthy granulations. On 4 September, the lesion was completely epithelialized.

Case 5 (J. H.) The patient was a 41-year old, colored male admitted 12 August 1952 for first- and second-degree flash burns of the face, neck, upper trunk, volar surfaces of both arms, the right forearm, and the right palm, sustained while tending a furnace. Of the burned area, 90% was first-degree. All the burns, except those on the face, were sprayed with aeroplast. There was almost immediate subjective relief of pain in the sprayed areas; the burns on the face remained painful. The first-degree burns were completely epithelialized by 18 August, there having been no difference in healing time between those treated with exposure and those treated with aeroplast.

Case 6 (M. W.) The patient was a 29-year old, colored male admitted from another hospital 2 September 1952, to the prison ward for a deep laceration involving joint capsule and a deep, second-degree friction burn of the left shoulder, measuring 14 x 17 cm, and two second-degree friction burns of the left wrist and dorsal surface of the left forearm, measuring 10 x 4 cm and 15 x 6 cm respectively. These injuries were sustained in a stolen truck on 30 August 1952. The patient was first seen by us on 3 September, four days after the injury, at which time the shoulder lesion was clean and the forearm lesions were grossly infected with B. pyocyaneus. The vaseline-gauze dressings were replaced with aeroplast; this was changed every three days. On 11 September, the patient was transferred to prison. At this time, the B. pyocyaneus infection of the forearm lesions had neither improved nor progressed; the shoulder lesion was 50% healed, with zones of re-epithelization from 1.0 to 4.0 cm wide.

Case 7 (G. D.) The patient was a 38-year old, white waitress first seen in the Out Patient Department on 11 September 1952, with circular, second-degree burns of all fingers and the dorsum of the left hand, sustained through immersion in boiling water (Fig. 13). Aeroplast was applied within 30 minutes with no debridement, the blisters were exicised on the third day and aeroplast reapplied. The patient was given a small supply of aeroplast and instructed to "touch-up" any cracks that developed. She was seen every other day and at no time was there evidence of infection. The aeroplast was changed again on 19 September. On 23 September 1952, there was complete healing with full function. Throughout this period she continued working as a waitress, using her injured hand, although she was advised to keep the hand protected.

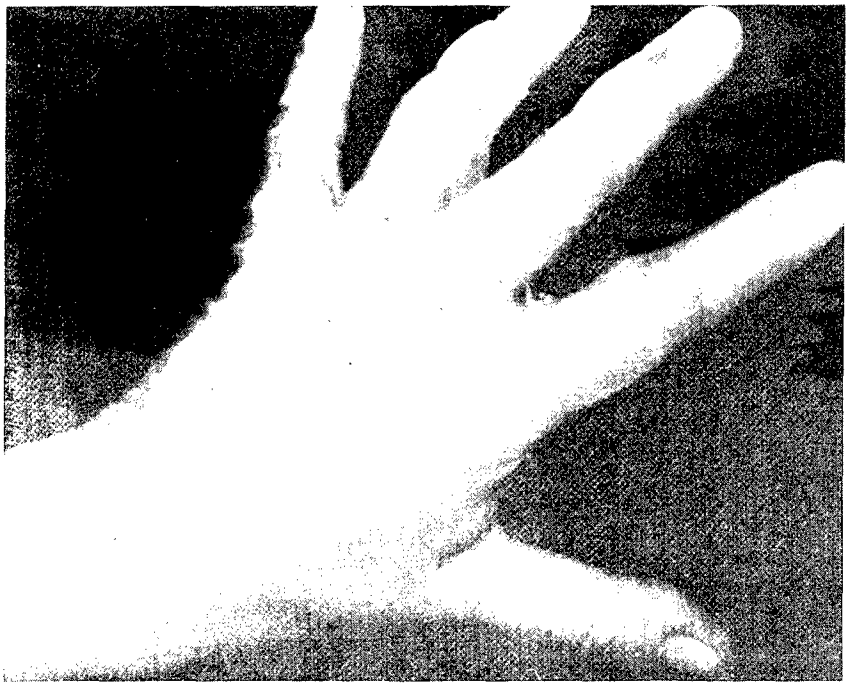


Figure 13. (A) Case 7, G. D. Second-degree burn of left hand with aeroplast dressing. Note blister formation.

Figure 13. (B) Case 7, G. D. Same burn after excision of blisters and application of aeroplast.

Figure 13. (C) Case 7, G. D. Same burn with complete re-epithelization 12 days post-burn.

Figure 13. (D) Note removal of aeroplast dressing as an entire "glove".

Case 8 (B. S.) The patient was a 36-year old, white male admitted 12 September 1952, with a first-, second- and third-degree burn involving the posterior surface of the distal half of the left arm, the elbow and the left forearm. These were sustained in a freak accident in which the patient was waiting for a traffic light with his arm on the window sill of his car, when a gas explosion occurred in an open man hole. Aeroplast was applied with dramatic relief of pain. On the second hospital day, however, the patient signed out to seek private care.

Case 9 (M. B.) The patient was a 42-year old, white male seen in the Out Patient Department 17 September 1952, with first-degree flash burns of the posterior aspect of the neck and both shoulders (a vest-distribution), sustained in a rubber-cement fire. The patient complained bitterly of pain until the aeroplast was applied. The patient was instructed to return the following day, but failed to do so.

Case 10 (G. A.) The patient was an 11-year old, white girl first seen in the Out Patient Department 24 September 1952, with second-degree burns of the dorsal aspects of the third, fourth and fifth fingers of the right hand, sustained four days previously in a frying-pan fire. When seen, the blisters had ruptured, and aeroplast was applied without debridement. On 25 September, the blisters were excised and aeroplast reapplied. No other dressings were required and healing was complete, without infection, by 1 October 1952.

Case 11 (A. B.) The patient was a 22-year old, white nurse who sustained first- and second-degree burns of the dorsal aspects of the third and fourth fingers, and the distal half of the dorsum of the left hand. Aeroplast was applied, with relief of pain. No change of dressing was required and complete healing occurred five days later.

Other Surgical Wounds:

The aeroplast dressing was successfully used on a wide variety of surgical wounds (Table 4). The results of treatment are summarized in Table 5. In most cases, one dressing applied in the operating room was sufficient until the sutures were removed. The advantages of the window-effect of transparency, and the elimination of dressing changes in most of these cases, proved not unacceptable to the hard-working house staff. The aeroplast was excellent for lacerations of the scalp, face (Fig. 14), neck and hands, areas which are poorly suited for gauze and adhesive tape dressings. Perhaps the most dramatic application of the aeroplast was its use on the abdominal wall, markedly excoriated by an ileostomy (Case No. 27, L. S.); there was almost immediate subjective relief of discomfort and 24 hours later there was an 80% clearing of the excoriations (Fig. 15). It was used with moderate success in one decubitus ulcer (Case 23, N. C.) and with marked success on a traumatic ulcer (Case 24, A. W., Fig. 16). Its use on open reductions of fractures made feasible the application of skin-tight plaster casts, since the bulk of the usual gauze dressings was eliminated. The sites of emergence of Kirschner wires from skin are often subject to low-grade infections. The use of aeroplast in two cases (Cases No. 30, H. M., and No. 31, J. W.) sealed off these areas effectively for three and four weeks respectively. The

Figure 14. Case 22, F. L. Laceration of face with aeroplast dressing

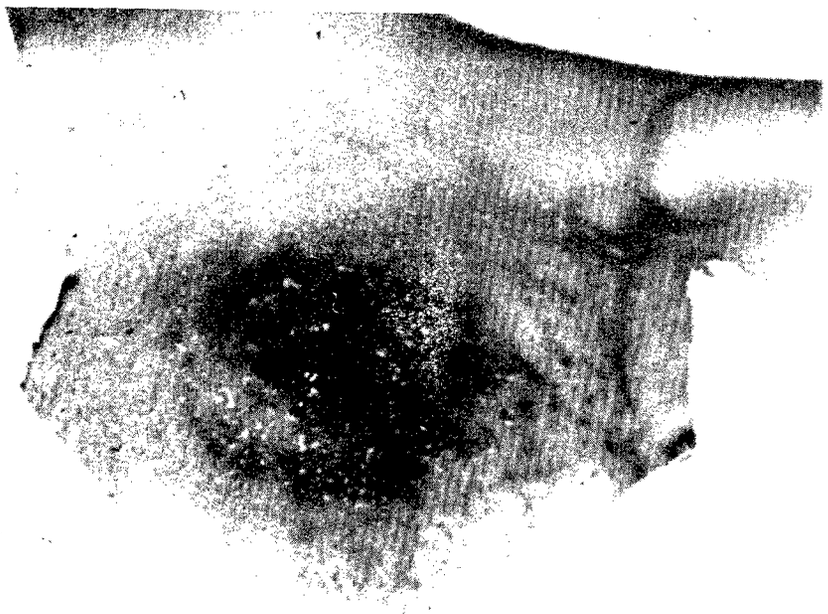


Figure 15. (A) Case 27, L. S. Ileostomy with excoriated surrounding skin

Figure 15. (B) Case 27, L. S. Ileostomy, 24 hours after application of aeroplast

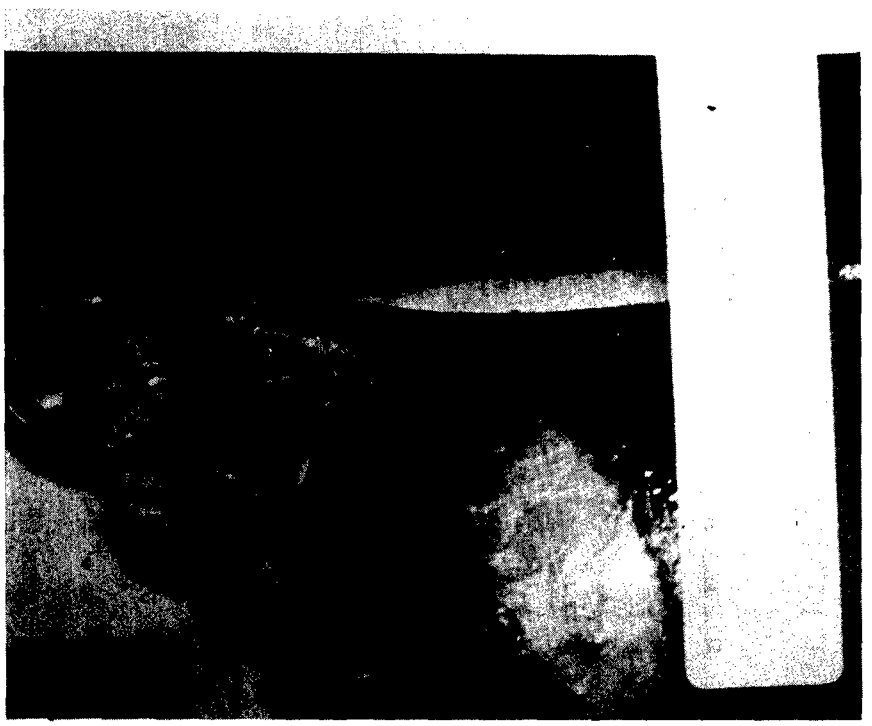


Figure 16. Case 24, A. W. Traumatic ulcer treated with aeroplast, completely epithelialized 16 days post-trauma

absence of infection in these two cases must be attributed at least in part to the aeroplast. One wound infection (Case 11, L. B.) was encountered. Four cases warrant comment:

Case 11 (L. B.) The patient was a 64-year old, white male with an indirect, left, inguinal hernia. A herniorrhaphy, performed on 3 September 1952, was dressed with aeroplast on the first post-operative day. On the fifth post-operative day, the wound was observed to be infected and from five to seven cc of dark red blood was aspirated foom the inferior end of the wound. The aeroplast was replaced with a gauze dressing and antiobiotics begun. The wound healed completely on the 17th post-operative day after the infection gradually subsided.

Case 25 (W. H.) The patient was a 42-year old, white male with a large stasis ulcer of the right heel, measuring 20 x 15 cm. Concurrent diagnoses: pulmonary tuberculosis, active; chronic alcoholism; Laennec's cirrhosis; and malnutrition. After a skin graft failed to take, the aeroplast dressing was applied on 26 September 1952. After 10 days, it was obvious there was no progression of healing. The aeroplast was therefore discontinued.

Case 26 (A. C.) The patient was a 65-year old, white female with diabetes and a severe weeping stasis dermatitis of both lower legs. It was decided to attempt to prevent a breakdown of the skin by protecting the legs with aeroplast. The aeroplast was discontinued after two days because of excessive accumulation of fluid underneath.

Case 29 (M. G.) The patient was a 45-year old, white female with the diagnoses: psychosis, manic-depressive type; obesity, severe; and varicose veins. A bilateral saphenous vein ligation was performed on 4 September 1952. Post-operatively the wounds were macerated by (1) a pendulous abdomen and pubic hairs abrading the upper thighs, and (2) urinary incontinence. On the second post-operative day, the macerated wounds were treated with aeroplast to exclude the urine. Gauze and adhesive were applied over the aeroplast to protect the plastic dressing against mechanical trauma from the pendulous abdomen. Under this regimen, the wounds healed in five days, and the macerated areas gradually returned to normal after 12 days.

Discussion

The aeroplast, originally designed as an emergency, initial local dressing for the mass treatment of thermal burns pending (1) the mobilization of existing medical resources, and (2) the evacuation of these burn casualties to centers for definitive therapy, must, in the light of clinical trials described in the foregoing, be regarded as a general surgical dressing with certain advantages and certain limitations. The evidence indicates that the essentials of a good surgical dressing are met: (1) no retardation of wound healing, (2) ability to maintain the sterility of a clean wound, (3) ease of application and removal, (4) transparency.

The chief drawback of the aeroplast proved to be the 30-45 second period of sharp "stinging" felt when the dressing was applied to a raw area. The "stinging" sensation was of the order of magnitude of the burning caused by

merthiolate or alcohol. It was felt that the following considerations tend to minimize the importance of this undesirable characteristic:

(1) The aeroplast does not cause "stinging" in first- and third-degree burns, and in granulating wounds.

(2) The burning sensation lasts only 30-45 seconds, and is no worse than that caused by standard antiseptics such as merthiolate and alcohol.

(3) All surgical wounds can be dressed while the patient is still under anesthesia.

(4) The problem of burning is trivial in relation to the time and personnel saving advantages of the aeroplast in the treatment of burn casualties of disaster proportions.

Use of the aeroplast as an initial, temporary dressing to prevent further wound contamination, opens channels of use in front-line battalion aid stations, in bomber aircraft on extended missions over hostile territory, in airfield crash ambulances, and in military and civilian rescue operations following atomic attack.

Use of the aeroplast as a definitive dressing for surgical wounds affords the advantages previously described.

Summary

A general surgical dressing (aeroplast), utilizing a modified polyvinyl plastic dispensed from an aerosol bomb, is presented.

The results of two months of clinical trials with the aeroplast are presented.

The advantages and limitations, and the possible uses of the aeroplast dressing are discussed.

Table 4

SKIN-GRAFT DONOR SITES

Case No.	Name	Sex	Age	Primary Dx	Infection	Healing Time
1	E.J.	M	27	Third-degree burn	No	18 days
2	F.F.	M	65	Stasis ulcers, left leg	No	13 days
3	W.H.	M	42	Stasis ulcers, right leg; Pulmonary tuberculosis, active; Chronic alcoholism	No	10 days after application of aeroplast. Incomplete healing for 76 days prior to aeroplast.
4	G.W.	M	57	Gangrene, right buttock and scrotum; Malnutrition; Severe chronic alcoholism	No	9 days
5	M.W.	M	50	Paraplegia; Skin defect, left foot, secondary to extravasated infusion	No	12 days
6	T.W.	M	49	Third-degree burn; Korsakoff's syndrome	No	8 days
7	P.M.	M	65	Chronic alcoholism; Traumatic ulceration, left leg	No	7 days
8	J.S.	M	59	Malnutrition; Stasis ulcers, left leg	No	9 days

Table 5

SURGICAL WOUNDS TREATED WITH AEROPLAST

Wound	Number
Appendectomies	4
Laparotomies	2
Cholecystectomies	2
Herniorrhaphies	5
Open Reductions of Fractures	3
Kirschner Wire Fixations	2
Incision and Drainage of Abscesses	2
Lacerations	4
Ulcers, Skin	3
Gastrostomy and Ileostomy	2
Saphenous Vein Ligation	1
Stasis Dermatitis	1
TOTAL	31

Table 6

RESULTS OF SURGICAL LESIONS TREATED WITH AEROPLAST

Case No.	Name	Sex	Age	Primary Wound	Healing Time (Days)	Infection
1	T.C.	M	20	Appendectomy	7	No
2	M.C.	M	20	Appendectomy	6	No
3	A.W.	M	34	Appendectomy	9	No
4	E.G.	F	20	Appendectomy; Pregnancy 5 mos.	6	No
5	H.K.	M	63	Exploratory Laparotomy	10	No
6	D.L.	M	61	Exploratory Laparotomy	8	No
7	L.M.	M	43	Cholecystectomy	7	No
8	E.A.	F	31	Cholecystectomy	13	No
9	J.E.	M	69	Herniorrhaphy, Bilateral	8	No
10	F.I.	M	48	Herniorrhaphy, Bilateral	Right - 7 Left wound dehisced on first post operative day	No
11	L.B.	M	64	Herniorrhaphy	17	Yes
12	O.O.	M	38	Herniorrhaphy	6	No
13	D.H.	M	80	Herniorrhaphy	13	No
14	R.S.	F	77	Smith-Peterson Intramedullary nailing of hip	9	No
15	M.S.	F	32	Open Reduction, left femur	5	No
16	E.M.	F	35	Open Reduction, left radius and ulna	11	No
17	M.S.	F	34	I & D of large abscesses, both buttocks	11	No
18	G.T.	M	65	I & D of carbuncle, left temporal scalp, required stamp graft	11	No

Table 6 (continued)

Case No.	Name	Sex	Age	Primary Wound	Healing Time (days)	Infection
19	H.B.	M	32	Laceration, left hand	9	No
20	A.M.	F	34	Laceration, left hand	6	No
21	T.B.	M	43	Laceration, neck, 15 cm long	4	No
22	F.L.	M	67	Laceration, face, 10 cm long	4	No
23	N.C.	F	70	Decubitus ulcer, 7.0 x 5.0 cm	In 30 days ulcer was 2.0 x 1.0 cm	No
24	A.W.	M	31	Traumatic ulcer, left foot, 7 x 3 cm	16	No
25	W.H.	M	42	Stasis ulcer, right heel, 20 x 15 cm	No healing	
26	A.C.	F	65	Stasis Dermatitis, both lower legs	No healing	
27	L.S.	M	32	Excoriated abdomen from ileostomy	1	No
28	J.S.	M	25	Excoriated abdomen from gastrostomy	1	No
29	M.G.	F	45	Bilateral saphenous vein ligation	5	No
30	H.M.	M	65	Kirschner wire fixation, supracondylar fracture, right femur	--	No
31	J.W.	M	34	Kirschner wire fixation, transverse fracture, right tibia and fibula	--	No

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